RADIATION SAFETY MANUAL

Environment, Safety, Health and Assurance Office
First Edition
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Ames Laboratory
Iowa State University
Ames, Iowa

EMERGENCY INFORMATION

In the event of an accident involving radioactive material or a radiation-producing device, contact:

(During normal business hours)

RADIATION SAFETY OFFICER..........................294-7922

(After hours, weekends, holidays)

PLANT PROTECTION SECTION.......................294-5111

If the accident involves **personal injury** or **fire**, immediately call: **911**

PREFACE

This Radiation Safety Manual has been prepared by the Laboratory's Health Physicist, and approved by the Ames Laboratory ALARA Committee; it is intended to be a "hands-on" guide for those Laboratory employees using or intending to use radioactive materials and/or radiation-producing devices in the conduct of their research activities. To produce this Manual, Ames Laboratory asked for and received permission from Iowa State University (ISU), to use as a guide, their copyrighted "Radiation Safety Manual, version 10, May, 1996", which was written by personnel in their Department of Environment Health and Safety (EH&S). Since many personnel involved in research activities are associated with *both* ISU and Ames Laboratory, every effort was made to maintain consistency between the two Manuals, but to include differences in Ames Laboratory's policies and procedures, where necessary. The Laboratory is very appreciative of University's cooperative spirit and assistance in this effort.

The scope and content of the Manual has been intentionally limited to that information which is considered essential to ensuring the safe use of radioactive materials and radiation-producing devices. For this reason, extensive reproductions of relevant regulations and guidelines often found in documents of this nature have been excluded from the Manual. Such standard references, however, are cited where appropriate. To further enhance the Manual's readability and usefulness, the contents have been organized into sections that are titled and easily referenced from the Table of Contents. It is hoped that this format will enable researchers to quickly find the specific information that they require.

As is true of most areas of Ames Laboratory safety, the extent to which radiation safety is practiced in the laboratory depends not only on the quality of the safety-related information provided, but also on the willingness of the individual researcher to put this information into practice. This Manual is intended to provide sufficient information to enable radiation safety practices at Ames Laboratory to be of the highest quality. It is, however, the responsibility of each student or member of the staff or faculty who works with radioactive materials or radiation-producing devices to become familiar with the contents of this Manual and to observe those procedures and requirements contained herein which are applicable to their particular work.

For individuals who are seeking initial approval to use radioactive materials at Ames Laboratory, a checklist detailing the necessary steps for obtaining approval and initiating the use of radioactive materials has been prepared. This checklist is included as Appendix E to the Manual.

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1.0 INTRODUCTION

The use of radioactive materials and radiation-producing devices in our society has expanded continuously since the discoveries of radioactivity and x-rays in the late nineteenth century. This has been particularly evident at facilities like Ames Laboratory where such materials and devices have become increasingly important tools in research and teaching.

As the use of materials and devices that contain or produce ionizing radiation has grown, so has our understanding of the potential hazards associated with their use. These hazards began to be appreciated in the early part of this century when adverse health effects were first observed in individuals who had been exposed to ionizing radiation. Concern over health risks associated with radiation exposure led very early to recommended exposure limits and, ultimately, to mandatory limits and strict regulatory controls governing the possession and use of all sources of ionizing radiation.

Current limits for radiation exposure are based upon the conservative assumption that there is no completely safe level of exposure. In other words, even the smallest exposure has some probability of causing a late effect such as cancer or genetic damage. This assumption has led to the general philosophy and regulatory requirement of not only keeping exposures below recommended levels or regulatory limits, but of also maintaining all exposures As Low As is Reasonably Achievable (ALARA). This is a fundamental tenet of current radiation safety practice.

This Manual presents the information and procedures that must be understood and practiced in order to ensure that all uses of ionizing radiation at Ames Laboratory are in compliance with existing regulatory requirements. Any resultant radiation exposures must be maintained ALARA.

2.0 REGULATORY REQUIREMENTS

2.1 Radiation-Producing Devices

There are two basic types of radiation-producing devices currently in use at Ames Laboratory, both of which produce x-rays. These two types are classified as incidental devices and intentional devices.

An incidental x-ray device produces x-rays that are not wanted or used as part of the designed purpose of the machine. Shielding of an incidental x-ray device should preclude significant exposure. Examples of incidental systems that are present in the Laboratory are computer monitors, televisions, electron microscopes, high-voltage electron guns, electron beam welding machines, and electrostatic separators. Intentional x-ray devices are designed to generate x-rays for a particular use. Examples of these devices present at the Laboratory are analytical x-ray diffraction systems and analytical x-ray fluorescence systems.

American National Standard (ANSI) N43.3 is the standard that applies to both of these types of radiation-producing devices. ANSI N43.3 defines incidental x-ray devices as exempt shielded systems, which are inherently safe and require review only upon purchase or modification. With regard to intentional x-ray devices, the ANSI defines analytical x-ray systems as either *open beam* or *closed beam* and has specific safety guidelines for each type. Ames Laboratory's Analytical X-ray Safety Policy uses the ANSI N43.3 as a base document for radiation safety for these devices.

2.2 Radioactive Materials

The possession and use of radioactive materials in the United States is governed by strict regulatory controls. The federal regulation governing the use of radioactive materials at Ames Laboratory is 10 CFR 835. To implement this regulation, the Ames Laboratory Radiological Protection Program (RPP) has been written to state how each of the safety requirements will be accomplished at the Laboratory. The RPP has a number of associated policies and procedures used for each functional element of the program. In addition, the Ames Laboratory Site-Specific Radiological Control Manual is used to fulfill radiological control performance commitments of the RPP. These documents are available for review at any time at the ESH&A Office in G40 TASF, and are distributed to Laboratory employees, as appropriate.

3.0 ADMINISTRATIVE CONTROLS

It is the policy of Ames Laboratory to both allow and facilitate the use of [redacted] teaching. At the same time, Ames Laboratory is committed to ensuring that all uses of these materials and devices are in compliance with regulatory requirements and that resultant radiation exposures are As Low As is Reasonably Achievable (ALARA). Toward this end, the Ames Laboratory has established specific administrative entities with responsibilities for controlling the use of radioactive materials and radiation-producing devices at Ames Laboratory.

3.1 ALARA Committee

In accordance with the specific requirements of Ames Laboratory's Radiological Protection Program (RPP) an ALARA Committee has been established. The Committee consists of eight members of Ames Laboratory's staff and faculty appointed by the Director for terms of three years. The principal function of the Committee is to oversee the implementation of Laboratory policies and procedures for the safe use of radioactive materials and radiation-producing devices. In addition, the ALARA Committee reviews all requests for use of radioactive materials and radiation-producing devices, reviews records of personnel dosimetry, and decides whether or not authorization for use is to be granted.

3.2 Radiation Safety Officer (RSO)

The Radiation Safety Officer is the individual (the ESH&A Office Health Physicist) who has the responsibility for the day-to-day administration and operation of Ames Laboratory's Radiological Protection Program. This individual is also a permanent member of the ALARA Committee. At Ames Laboratory, the RSO is assisted by a Radiological Control Technician (RCT) to ensure the safe use of radioactive materials and radiation-producing devices.

3.3 Environment, Safety, Health and Assurance Office (the ESH&A Office)

At Ames Laboratory, the radiation safety program and support staff are administratively located within the ESH&A Office. The ESH&A Office has the responsibility for managing all Laboratory health and safety programs including radiation, chemical, industrial hygiene and biological safety. The radiation safety program includes accountability of radioactive materials and radiation producing devices, personnel training, laboratory surveys and inspections, waste handling, and personnel dosimetry.

4.0 AUTHORIZATION PROCESS

The ALARA Committee must specifically authorize each activity, which involves the use of radioactive material or a radiation-producing device.

4.1.1 Readiness Review and Application for Use

Any Group activity that involves the use of radioactive materials or analytical x-ray systems must have the following information before operation:

1) The necessary forms for an Activity Readiness Review or Activity Status Review of the activity.

2) An Application for use of radioactive materials or analytical x-ray.

These forms should be completed, as instructed, and returned to G40 TASF to initiate the Review process.

The Application for Use form should also be completed and returned as soon as possible to G40 TASF to the Health Physicist. The "Individual User" in Item #1 on the form is the supervisor of the radioactive use area or analytical x-ray systems. <u>Note: It is not necessary to list all users on the application - reference should be made on the form to "see current list of users" for all other users of the area (See descriptions below).</u> The Application for Use will be reviewed by the ALARA Committee who will then issue a Use Authorization. The Use Authorization will become a permanent part of the Activity Review file.

{<u>**Note:**</u> **The Activity cannot be approved until the Use Authorization been issued and is part of the Review file. The Authorization Approval serves to authorize <u>individuals</u> to perform the activity and the Activity Review is for the <u>activity</u>.**}

4.1.2 Filling Out the Application for Initial Use

The individual who is to be in charge of the activity, referred to as the "activity supervisor," begins the authorization process by completing an "Application for use of Radioactive Materials (Appendix A) or an "Application for Use of Radiation Producing Devices" (Appendix B). Application forms are available from the ESH&A Office. The application must include detailed information in three general categories: Activity Description, Facility Description and Information on Users.

4.1.3 Activity Description

(a) Scope of activity: purpose and experimental procedures to be used.
(b) Radionuclides: type and amount.

(c) Radiation-producing devices: type and energy of radiation to be produced.
(d) Radiation levels: levels expected in the facility and in neighboring areas; potential for release of radioactive materials.
(e) Equipment: assay, monitoring and dosimetric instruments available or needed; procedures for using these instruments.
(f) Safety procedures: general, monitoring, waste handling.
(g) Records: receipt, use and disposal of radioactive material, and radiation surveys.
(h) Radioactive Waste: Amounts generated per experiment, per year, and types of solids and liquids generated per experiment. Building and rooms where waste will be collected.

4.1.4 Facility Description (see Subsection 12.1 for specific requirements)

(a) Location of use: building floor, room number, and group.
(b) Building plan drawing: (Available from Engineering Services Group or ESH&A)
   i. Radionuclide facility: locations of hoods, sinks, benches, exterior/interior walls, windows, doors, intended use and storage areas.
   ii. Radiation (machine) facility: location of radiation source, exterior/interior walls, windows, doors, shielding, direction of primary beam.
(c) Construction materials: floors, bench tops, hoods and sinks.
(d) Ventilation: air exchange rate for the laboratory and the number and type of hoods or glove boxes.
(e) Radiation safety equipment: shielding, waste containers, trays, absorbent paper, spill kit, type of survey meter.
(f) Occupancy of facility and adjacent areas: use of facility by individuals not approved for radionuclide work and use of areas adjacent to the facility.

4.1.5 Information on User(s)

(a) Personal: name, group, activity supervisor, Ames Laboratory address and phone number.
(b) Education and training: title and credit hours of any course taken in nuclear science, radiation safety or radionuclide use, an indication of whether Ames Laboratory's Radiation Safety Training Program has been completed (include the completion date).
(c) Laboratory experience: duration of experience, type and quantity of radionuclides used, the specific experimental procedures employed, procedures followed for laboratory safety and waste handling.

4.2 Review and Approval of Application

The completed application must be submitted to the ESH&A Office where it will receive an initial review. At this time, the Radiation Safety Officer (RSO) may require additional information from the applicant. If the application appears to be adequate, the RSO completes and signs an authorization form (see Appendix C). This form, together with the application and the RSO's recommendations, is forwarded to the ALARA Committee. Based upon its review of this material, the ALARA Committee decides whether authorization is to be granted. If the application is approved, the chair of the ALARA Committee signs the authorization form, returns it to the ESH&A Office. Note: The approved authorized use who forwards it to the activity supervisor. Any possible conditions under which authorization is granted are also specified on the authorization form.

Should approval not be granted, a written notification, which includes an explanation for this decision, is forwarded to the activity supervisor. This notification includes a description of the possible modifications to the activity that would be necessary in order for it to be approved.

4.3 Application to Amend Use

Changes in an activity supervisor's authorized use of radioactive material or radiation-producing device as originally granted by the ALARA Committee may be requested in the form of a memorandum to the ESH&A Office. Minor changes such as additional personnel or increased possession limits are reviewed and approved by the Radiation Safety Officer (RSO). More extensive changes will be subject to the same review and approval process as was the original application.

5.0 TRAINING REQUIREMENTS

Current federal regulations require that individuals who will be working with sources of ionizing radiation be provided with appropriate training prior to beginning work with such materials or devices. At Ames Laboratory, several forms of general and specialized training are provided by the ESH&A Office in order to ensure that individuals using radioactive materials or radiation-producing devices have sufficient knowledge to conduct their work safely. Ames Laboratory requires each employee to complete a Training Needs Questionnaire, which is available from the ESH&A Office.

5.1 Radioactive Material Users

All individuals who use radioactive materials at Ames Laboratory must possess a basic understanding of ionizing radiation and its potential hazards as well as knowledge of the particular rules and regulations governing radioactive material use. In order to accomplish this objective, the ESH&A Office provides Radiological Worker (RW) I or II training to individuals seeking authorization for use of radioactive material. RW I and II training may be accomplished by using the Ames Laboratory study guides to prepare for a 50 question examination. All Ames Laboratory Radiological Training is federally mandated training, promulgated by the U.S. Department of Energy. The ALARA Committee will not authorize an individual for use of radioactive material until they have satisfactorily completed this training program.

In addition to the general training requirements for radioactive material use, an individual who desires to be authorized as the activity supervisor must also provide evidence that he or she has appropriate *experience* with the types and quantities of radionuclides that he or she wishes to work with. When, in the judgment of the ALARA Committee an applicant has insufficient experience to act as the activity supervisor, the applicant may be advised to work under the supervision of another approved activity supervisor until sufficient experience can be obtained.

5.2 Users of Radiation-Producing Devices

All individuals who use radiation-producing devices at Ames Laboratory must possess a basic understanding of ionizing radiation and its potential hazards as well as knowledge of the particular rules and regulations governing radiation-producing devices. In order to accomplish this objective, the ESH&A Office provides Radiological Worker (RW) II Training for Use of Analytical X-ray Systems, (RWII(X). RWII(X) training may be accomplished by using the Ames Laboratory RWII(X) study guide to prepare for a 50 question examination. The ALARA Committee will not authorize an individual for use of analytical x-ray systems until they have satisfactorily completed this training program. In addition to the ESH&A Office training, the Group Leader provides training on the specifics of the particular system or device including its typical radiation levels and safety features, shielding techniques, radiation-related health risks, and operating requirements.

6.0 RESPONSIBILITIES

6.1 Responsibilities of the Activity Supervisor

The individual authorized by the ALARA Committee as the *activity supervisor* on an activity involving the use of radioactive material or a radiation-producing device *is responsible for all activities conducted under the scope of that authorization*. This includes responsibility for ensuring that:

1. All individuals working on the activity are appropriately trained and supervised.
2. The ALARA Committee has formally authorized all individuals working on the activity.
3. All rules, regulations, and procedures for the safe use of radioactive materials or radiation-producing devices are observed on the activity.
4. An accurate record of the types, quantities, and locations of radioactive materials or radiation-producing devices in his or her possession is maintained.
5. The ESH&A Office is notified of any proposed changes in the storage or use of the radioactive material or a radiation-producing device prior to the implementation of such changes.
6. All uses of radiation are constantly evaluated to further reduce exposures to individuals (ALARA).
7. All radioactive sources or source material are protected from unauthorized access or removal.

6.2 Responsibilities of the Individual User

The individual user is ultimately responsible for the safe use of the radiation sources to which the user has access. Each user shall:

1. Keep their personal exposure as low as reasonably achievable.
2. Wear assigned personnel monitoring devices in an approved manner.
3. Be familiar with and comply with all work smart standards applicable to their work.
4. Be familiar with the nature of all radiation sources in the work area and the extent of their potential risk, and use the appropriate procedures to minimize the risk.
5. Monitor the work area frequently for contamination.
6. Clean up minor spills immediately. DON'T LEAVE SPILLS FOR ANOTHER PERSON TO CLEAN UP.

7. Dispose of radioactive waste in an approved manner.
8. See that sources, containers, and the area are properly labeled and posted.
9. Assist the laboratory supervisor in maintaining the required records and inventories.
10. Prevent unauthorized persons from having access to the radiation sources.
11. Protect service personnel, allowing no maintenance or repairs of the facility or equipment unless approved by the activity supervisor and the Radiation Safety Officer.
12. Notify the activity supervisor and the ESH&A Office of any expected or unexpected difficulties that may affect the safe use of radioactive materials.
13. Take no action that would interfere with the responsibilities of their activity supervisor.

7.0 PROCUREMENT OF RADIOACTIVE MATERIAL

In order to ensure control of the types and amounts of radioactive materials entering Ames Laboratory, all purchases of these materials must be approved and processed by the ESH&A Office.

7.1 Ordering Radioactive Material

The procedure by which radioactive material may be ordered is as follows:

1. The activity supervisor (or their designee) initiates the procurement process by phoning the ESH&A Office concerning the proposed order.
2. The ESH&A Office checks the type and amount of the radionuclide to be ordered against that for which the user is authorized. If the two are consistent, the ESH&A Office will assign a log number to the order.
3. Once the authorized user has a log number for the order, he or she may then fill out a purchase order for the material (Purchasing will not issue a P.O. number if the order has not been assigned a log number).
4. The vendor must be instructed to reference the following on the packing slip accompanying the order:

    a. The name of the activity supervisor.
    b. The name of the person who placed the order.
    c. The log number assigned to the order.

In accordance with Ames Laboratory requirements, the vendor must also be instructed to send the shipment to:

Environmental, Safety, Health and Assurance
G40 TASF
Ames Laboratory
Iowa State University
Ames, Iowa 50011

See Appendix D for an example of a properly completed purchase requisition.

7.2 Receipt and Delivery of Radioactive Material

Upon receipt of a radionuclide shipment, the ESH&A Office staff check the package and its contents for contamination and to ensure that any existing radiation levels are within the regulatory requirements. The ESH&A Office then enters the type and amount of the radionuclide received into its radioactive material accountability system.

Once the ESH&A Office package receipt procedure has been completed, the ESH&A Office delivers the shipment to the user's laboratory. Accompanying each package is an inventory card stating the amount of the particular radionuclide present. This must be returned to the ESH&A Office once the radioactive material has been used or consigned to waste.

8.0 STORAGE AND TRANSFER OF RADIOACTIVE MATERIAL

Any proposed transfer of radioactive material between individuals at Ames Laboratory or between an Ames Laboratory employee and another individual not associated with Ames Laboratory must be approved by the ESH&A Office and the Packaging and Transportation (P&T) Manager before the transfer takes place.

8.1 Security of Radioisotopes

Security of radioactive materials must be in place at all times. All locations where radioactive materials are present must be in constant attendance by the trained user, or otherwise locked or secured to prevent unauthorized removal or tampering.

8.2 Storage of Radioisotopes

Storage of radioactive materials shall be in secured or locked cabinets, refrigerators, freezers or waste areas, unless attended by the user. Radioactive materials shall be stored in sealed containers in such a way as to prevent accidental spillage or breakage, and to prevent release into the air. If the nuclide requires shielding, it shall be stored in shielded containers in order to prevent doses to personnel accessing the storage areas.

If the radioactive material has been stored in a freezer, the material shall be thawed, opened and handled in a fume hood or biological safety cabinet. Aerosols from stored radioactive materials may cause contamination of adjacent areas and doses to personnel if not handled in the proper way after storage. All radioactive materials, whether in storage, waste or use, must be labeled with the radioactive warning symbol, the words "Caution, Radioactive Materials," the isotope, the date and the amount of radioactivity in dpm or microcuries.

8.3 Instructions for Transporting Radioactive Material

Requirements for the transportation of radioactive material at Ames Laboratory and to other institutions must take place in accordance with U.S. Department of Transportation (DOT) regulations and the Ames Laboratory procedure “Receipt, Transfer, and Shipment of Radioactive Materials.” Transporting may involve walking or driving radioactive material to another Ames Laboratory building, or shipping off-site. The ESH&A Office must be notified before any transfers take place. This is to insure that proper procedures are followed and movement of radioactive material is tracked. Any transfers of radioactive material (possession transferred from one activity supervisor to another) must be pre-authorized by the ESH&A Office.

8.4 Package Preparation

All packages used to transport radioactive material must be as defined in 49 CFR that will not leak under normal transportation conditions (like dropping or jarring). P&T must approve all shipping containers. If liquid is shipped, use at least two times the amount of absorbent needed to contain the entire volume, in case the container should break or leak. If you are not sure whether the container you plan to use is adequate, contact the P&T manager.

8.5.1 Local Transfers of Materials

Approval of a transfer of radioactive material between individuals at Ames Laboratory will depend primarily upon two things. 1) whether the individual who wishes to receive the material has been authorized by the ALARA Committee for the type and quantity of radioactive material involved; and 2) whether the individual has received authorization for the specific procedure(s) to be used. Should the proposed recipient for the material not be currently authorized for the material's use, he or she may submit an application requesting authorization. Only after authorization by the ALARA Committee will the ESH&A Office approve the transfer of material.

Whenever radioactive material is transported from one laboratory to another, the ESH&A Office must be notified of the following information:

1. When the material will need to be moved.
2. The names of the person sending and receiving the material (if different).
3. The sending and receiving locations.
4. The nuclide(s) being moved.
5. The chemical form of the isotope.
6. The total activity in mCi.
7. Number of containers.
8. Phone numbers of responsible persons.
9. Any special conditions.

8.5.2 Walking to Another Building

Prepare to move the radioactive material using an appropriate container (see packaging above). The outside of the package must have a radioactive warning label with the following information: the isotope, activity in dpm, µCi or mCi and date. Clearly identify the activity supervisor and one other contact in case of an accident or loss of the package. The package must be tested for removable contamination before it leaves its place of origin and after it reaches its destination. Contact the ESH&A Office to have the package checked for removable contamination.

8.5.3 Driving to Another Building

The transportation of radioactive material must be done in accordance with the requirements of the U.S. Department of Transportation (DOT). You must not move any radioactive material by vehicle without prior authorization by P&T and ESH&A. P&T will prepare necessary documentation, package the material in an approved shipping container, and perform the actual transport of your material. The sender's responsibility is to contact P&T and ESH&A in advance.

8.6 Off-Site Transfers

When preparing to ship radioactive material off-site, whether it is radioactive samples or a piece of equipment being returned for repairs, P&T and ESH&A must be informed in advance. Do not expect to send shipments out immediately. Federal regulations must be followed regardless of the quantity being sent.

Approval of a transfer of radioactive material to an individual at Ames Laboratory from an off-site, non-vendor source will also depend primarily upon whether the proposed recipient has appropriate authorization to possess and use the material. If the transfer is approved by P&T and the ESH&A Office, the individual supplying the material must be instructed to ship it directly to P&T where it will be processed in the same manner as are all radioactive materials entering Ames Laboratory.

In order for an individual at Ames Laboratory to receive approval to transfer radioactive material off-site, he or she must obtain evidence from the intended recipient that they have an appropriate state or federal license, when appropriate, that allows for the possession of the material. A copy of this license must be furnished to the ESH&A Office before approval of the shipment will be granted. When shipping to an off-site DOE facility or NRC Laboratory, it is required that prior authorization be obtained from the radiation safety staff at that location, preferably the Radiation Safety Officer. To initiate the shipment, the person sending the material must have the following information:

1. The name of the person sending the material.
2. Receiving Facility’s name and address.
3. The name of the person who will receive the material.
4. The Radiation Safety Officer's name and phone number at the receiving point.
5. A copy of the receiver's radioactive materials license, if not a DOE facility.
6. The nuclide(s) being sent.
7. The chemical form of each isotope.
8. The total activity in mCi for each isotope.
9. Number of containers in the shipment.
10. Any special conditions.

P&T staff will then instruct the shipper regarding the packaging of the material and the completion of appropriate shipping papers.

P&T will determine what package labeling is required. The condition of the package will be checked and a leak test performed by the ESH&A Office. Labels will be placed on the package, if required. If the package is found to be in order, P&T will transport the package to the Ames Laboratory mail room. Copies of the shipping papers, material return form, and any other paperwork will be made and kept on record at P&T and at the ESH&A Office Health Physics Group.

Remember that shipments of radioactive material must be planned well in advance. Allow at least two weeks prior to the desired shipping date.

8.7 Temporary Job Sites

On rare occasions instruments and devices that contain radioactive sources will be used at temporary job sites. The use of radioactive materials at temporary job sites must have the prior written approval of the Radiation Safety Officer.

9.0 RADIOACTIVE WASTE

9.1 Radioactive Waste Handling

The ESH&A Office is responsible for the collection, treatment, and disposal of all radioactive waste generated at Ames Laboratory. In order to facilitate these processes, radioactive material users are required to follow a number of specific procedures regarding radioactive waste generated in their laboratories: *(for more detailed information, see Ames Laboratory "Radioactive and Mixed Waste Disposal" and procedure "Preparation of Radioactive and Mixed Waste for Disposal.")*

1. Radioactive waste should be separated and labeled according to whether it contains very short-lived (i.e. half lives less than 15 days), short-lived (i.e. half lives between 15 and 90 days) or long-lived (i.e. half lives greater than 90 days) radionuclides.

2. Solid radioactive waste must be separated and labeled according to whether it is combustible (e.g. plastics, paper, etc.) or noncombustible (e.g. glass, metal, etc.). Each of the two waste containers required for this purpose should be lined with a plastic bag that must be removed and sealed when full.

3. Sharp items such as needles and razor blades should not be placed in the solid waste container but should be placed in a cardboard box, glass bottle or "sharps" container. Lead source containers and source vials must also be held separately from other solid waste.

4. Liquid radioactive waste should be separated and labeled according to whether it is aqueous (or miscible in water) or organic. Organic liquids which are flammable (e.g. contain toluene or xylene) must be placed in containers specifically approved for flammable liquids.

5. All radioactive waste awaiting collection by the ESH&A Office should be properly packaged and labeled, and placed in a designated waste storage area. Solid and liquid waste containers, plastic bags, and radioactive waste labels are supplied by the ESH&A Office.

   FOR RADIOACTIVE WASTE COLLECTION PHONE the ESH&A Office at 4-9277

9.2 Radioactive Waste Minimization

Each user is encouraged to develop methods and procedures to reduce the amount of radioactive waste generated. Waste minimization techniques could include:

1. Periodically review procedures to ensure that unnecessary waste is not being generated. Use less radioactive material, recycle when possible, etc.

2. Be sure to place only radioactive waste in the radioactive waste containers. Normal trash should be segregated and disposed of separately.

3. Work on easily decontaminated surfaces (stainless steel trays or absorbent paper) to minimize the amount of waste generated from a small spill.

4. Wash glassware and survey for contamination. Radioactive wash water should be placed in liquid waste containers.

5. Material substitution - consider using non-radioactive methods.

6. Substitute very short-lived isotopes whenever possible.

9.3 Policy on Cleanup of Radioactive Contamination and Abandoned Radioactive Materials

Groups are responsible for decontamination of facilities and for identification and proper disposal of radioactive materials abandoned by their personnel. This policy does not apply to spaces that are authorized for the use and storage of radioactive materials, in which case the activity supervisor is responsible for corrective actions.

When contamination, or unknown or abandoned radioactive materials are discovered, the Group is responsible for all corrective actions. This may include notification of the ESH&A Office Health Physics Group for performing surveys and analyses, disposing of the materials, and/or decontaminating the laboratory.

The ESH&A Office will notify the Group Leader in writing when contamination, or unknown or abandoned radioactive materials are discovered. The Group will have thirty (30) days to complete the corrective action. After 30 days, the ESH&A Office will assume responsibility and complete the task unless the ESH&A Office and the responsible Group agree otherwise.

10.0 PERSONNEL EXPOSURE

The radiation safety program, administered by the ESH&A Office at Ames Laboratory, has as a primary goal the maintenance of all personnel radiation exposures below regulatory limits and As Low As is Reasonably Achievable. (ALARA). This is a fundamental tenet of current radiation safety practice and is a regulatory requirement to be followed by all occupational users of radioactive materials.

10.1.1 Occupational Dose Limits

Current limits for occupational radiation exposure have been established at levels which, in light of present knowledge, will: (1) prevent all acute radiation effects (e.g. erythema, epilation); and (2) limit the risks of late effects such as cancer or genetic damage to very low, "acceptable" levels. These limits can be found in Title 10, Code of Federal Regulations, Part 835. These limits are based on external, internal, and external plus internal exposures. To better understand the annual occupational exposure limits set by these regulatory agencies, the definitions of these limits are discussed below:

10.1.2 External Dose

Shallow-Dose Equivalent (SDE) is the dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue. [10 CFR 835.2(b)]

Eye (Lens) Dose Equivalent (LDE) is the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm. [10 CFR 835.2(b)]

Deep-Dose Equivalent (DDE) is the dose equivalent derived from external radiation at a tissue depth of 1 cm in tissue. [10 CFR 835.2(b)]

10.1.3 Internal Dose

Committed Dose Equivalent (CDE) is the dose equivalent to organs or tissue that will be received from an uptake of radioactive material.

Committed Effective Dose Equivalent (CEDE) is the dose equivalent for the whole-body from an uptake of radioactive material.

10.1.4 Sum of External and Internal Doses

Total Organ Dose Equivalent (TODE) is the dose equivalent to the maximally exposed organ or tissue from external and internal sources of ionizing radiation.

TODE = DDE + CDE

Total Effective Dose Equivalent (TEDE) is the dose equivalent to the whole-body from the combination of external and internal sources of ionizing radiation.

TEDE = DDE + CEDE

Table 1 provides a summary of the current annual occupational dose limits for external and internal exposures.

TABLE 1. Annual Occupational Dose Limits for Adult Workers

Type of Dose	Limit
Shallow Dose Equivalent, Skin of the Whole-body	50 rem
Shallow Dose Equivalent, Max., extremity	50 rem
Eye Dose Equivalent to Lens of the Eye	15 rem
Total Organ Dose Equivalent	50 rem
Total Effective Dose Equivalent	5 rem

In addition, internal exposure limits are addressed through the establishment of "annual limits on intake" (ALI). These values represent the derived limit for the amount of radioactive material taken into an adult body by inhalation or ingestion in a year (in either single or multiple events) that would result in the individual receiving a committed effective dose equivalent of 5 rem or a committed dose equivalent of 50 rem.

10.2 Regulatory Dose Limits to Declared Pregnant Workers

Because of the increased susceptibility of the unborn child to damage from ionizing radiation, the National Council on Radiation Protection and Measurement (NCRP) recommends that the whole body radiation dose received by a female worker during the 9 months of her pregnancy not exceed 500 mrem (i.e. 10% of the annual occupational dose limit).

The regulations only apply when a worker *voluntarily* declares her pregnancy in writing. If a declaration of pregnancy is made, the worker grants consent to her employer to limit her dose to a TEDE of 500 mrem throughout the entire pregnancy. If no declaration is made to the employer, her occupational dose limits are not restricted.

A declaration of pregnancy must be made to the Radiation Safety Officer in writing and noted by the ALARA Committee. The "Declaration of Pregnancy" form can be found in Appendix H. The declared pregnant female must also notify her supervisor when she is no longer pregnant (undeclaring).

10.3 Regulatory Limits for Dose to an Unborn Child

The dose to the unborn child during the entire pregnancy due to occupational exposure of a declared pregnant worker must not exceed 500 mrem. The dose will be the sum of the deep dose equivalent (DDE) to the declared pregnant worker and the dose to the unborn child from radionuclides within the unborn child and the declared pregnant worker. The records of dose for the unborn child will be permanently maintained in the declared pregnant worker's dosimetry files.

10.4 Occupational Dose Limits for Minors

A minor is anyone under 18 years of age. The dose limits for minors is 100 mrem/year TEDE or 10% of any annual occupational dose limit specified for adult workers in section 10.1.

10.5 Regulatory Limits for Dose to Individual Members of the Public

In general, the limits for dose to non-radiation workers and members of the public are two percent of the annual occupational dose limits. For the whole body dose, this would equal a TEDE of 100 mrem/year.

11.0 PERSONNEL MONITORING

A number of devices and methods exist for assessing an individual's exposure from ionizing radiation. Whether or not one or more of these personnel monitoring methods is employed for a given situation will depend upon a number of factors (e.g. type and quantity of radioactive material used, amount of time spent working with the material, etc.) which together determine the particular exposure potential.

11.1 Personnel Dosimeters

10 CFR 835 requires that any individual who is likely to receive more than 100 mrem annual occupational dose be monitored for radiation exposure. There are a number of types of materials or devices that are used to assess an individual's cumulative external radiation dose.

At Ames Laboratory the commonly used dosimeter is the thermoluminescent dosimeter (TLD). The TLD consists of a small chip of material (e.g., LiF or $CaF2$) which, when heated after an exposure to penetrating radiation, gives off light in proportion to the dose received. In Ames Laboratory research laboratories where analytical x-ray systems are used, TLDs are commonly used within rings. Ring TLDs are also worn by individuals handling relatively large quantities of energetic beta or gamma emitting radionuclides, e.g., P-32, when these isotopes are used.

In order for a dosimeter to provide an accurate indication of an individual's dose, it must be worn properly. For assessing whole body doses (the most common purpose of a TLD), the dosimeter should be worn on some area of the torso such as a breast pocket, lapel, or belt. If a protective lead apron is worn and only one dosimeter has been issued, it should be worn on the lapel. If a second badge has been issued, it should be worn under the apron. Ring badges should be worn beneath gloves with the sensitive surface on the palm side of the hand.

11.2 Bioassays

Assessing internal radiation exposures is far more difficult than the determination of external exposure. Most of the activities conducted at Ames Laboratory generally do not create situations in which internal exposures would become a problem. Procedures for this purpose are collectively termed "bioassays." For many water soluble compounds labeled with low energy beta emitters (e.g., H-3, C-14), urinalysis bioassay is conducted utilizing liquid scintillation counting. For radionuclides of iodine, internal exposure may be assessed by using a NaI scintillation probe to externally measure the amount of ionizing radiation emitted from the thyroid.

In general, urinalyses are performed by Ames Laboratory only for unusual situations such as accidents involving potential radionuclide uptake or for certain experimental procedures where ingestion or inhalation of radionuclides is possible.

11.3 Personnel Exposure Records/Reports

10 CFR 835 requires monitoring of any radiation worker who is likely to receive 100 millirem of annual occupational dose in the course of normal job duties. Part 835 requires that annual reports of occupational doses be given to those individuals meeting this monitoring requirement. At Ames Laboratory, all monitored personnel will receive an annual occupational dose report. An annual report of occupational doses must be given to monitored individuals. A report must also be supplied to monitored individuals upon termination or upon request by that individual. The results of all personnel monitoring are maintained on file by the Health Physics Group.

Personnel monitoring results are reviewed by the ESH&A Office Health Physics Group to assure that radiation doses are being kept ALARA. Doses that exceed the Ames Laboratory administrative limit, as defined by the RPP, will be reviewed and investigated by the ALARA Committee. Each individual's dosimetry records are available upon request. Information on a person's radiation exposures is only released to the person directly or to a specified party authorized by the exposed individual. A permanent record is kept on file of this release information, dated and signed by the individual involved. An individual is notified immediately by the ESH&A Office whenever current monitoring results exceed what is reasonably expected, considering the nature of the work being done.

12.0 LABORATORY SAFETY

The potential hazards associated with working with radioactive materials and other sources of ionizing radiation can be minimized through the use of appropriately designed and constructed facilities and by adherence to standard safety rules and practices.

12.1 Facility Requirements

The majority of research laboratories at Ames Laboratory can be classified as chemical laboratories. In most cases, these laboratories are adequate for the use of radioactive materials. For certain types and uses of radioactive materials, however, additional facility requirements must be met. The specific requirements, which will vary from one situation to another, are determined by the Health Physics Group.

In general, the following are minimum facility requirements for use of radioactive materials:

1. Floors must have smooth, nonporous, easily cleaned surfaces. Appropriate floor materials include vinyl, tile, and sealed concrete.
2. Benches must have nonporous, easily decontaminated surfaces. Surfaces of high quality plastic laminate or stainless steel are preferable.
3. Sinks should be stainless steel or have seamless molded construction.
4. Hoods (when required) must be currently tested and certified by the ESH&A Office, preferably constructed of stainless steel or molded fiberglass construction. Airflow rates, measured at the hood front opening must be a minimum of 150 linear feet per minute.
5. The ventilation rate for the entire lab should be 5 to 10 air changes per hour. The actual rate required will vary with the potential for radionuclide release to the air within the particular laboratory.
6. Shielding shall be provided when appropriate (e.g. for laboratories using large quantities of gamma or high energy beta emitting radionuclides). Specific requirements will be determined by Health Physics on a case-by-case basis.

12.2 Procedures, Practices, and Rules for the Safe Use of Radioactive Materials

In general, both internal and external exposures to ionizing radiation can be maintained ALARA through the adherence by radioactive material users to a number of standard procedures, practices, and rules:

1. Smoking, eating or drinking shall not be permitted in radionuclide laboratories.
2. Food, beverages and their containers shall not be permitted in the laboratory.
3. Pipetting by mouth shall not be permitted in radionuclide laboratories.
4 Microwave ovens in radionuclide laboratories shall not be used for heating food or beverages for personal use.
5. Individuals who have not been approved for radionuclide use shall not work with or handle radioactive materials.
6. A "Caution-Radioactive Material" sign shall be conspicuously posted at each entrance (e.g. on the door) of a radionuclide laboratory. Such signs or labels shall also be affixed at locations within the laboratory where radionuclides are used or stored (e.g. hoods, refrigerators, microwave ovens, etc.). Also posted within the laboratory in a conspicuous place shall be a copy of "Emergency Rules" and a "Radiological Control Rules"
7. Radionuclide work areas shall be clearly designated and should, to the extent possible, be isolated from the rest of the laboratory. The work area shall be within a hood if the radioactive material to be used is in a volatile form.
8. All work surfaces shall be covered with absorbent paper that should be changed regularly to prevent the build-up of contamination.
9. Work involving relatively large volumes or activities of liquid radioactive material should be performed in a spill tray lined with absorbent paper.
10. Procedures involving radioactive materials should be well planned and, whenever possible, practiced in advance using non-radioactive materials.
11. Protective clothing appropriate for the work conditions shall be worn when working with radioactive materials. This includes laboratory coats, gloves, and safety glasses. Appropriate footwear must always be worn (sandals cannot be worn when working with radioactive materials).
12. Dosimeters shall be worn when working with relatively large quantities of radionuclides that emit penetrating radiation.
13. All containers of radioactive materials and items, suspected or known to be contaminated, shall be properly labeled (i.e. with tape or tag bearing the radiation logo and the word "radioactive").
14. All contaminated waste items shall be placed in a container specifically designated for radioactive waste. Sharp items such as

needles or razor blades shall be placed in a cardboard box, glass bottle or "sharps" container.

15. A radiation survey shall be performed by the radionuclide worker at the end of each procedure involving radioactive materials (the survey may be made using a portable survey instrument, wipes, or both depending on the radionuclides used). All items found to be contaminated shall be placed either in the radioactive waste container or an appropriately designated area. Any surfaces found to be contaminated shall be labeled and decontaminated as soon as possible. **The survey should always include a check of personnel for possible contamination. The ESH&A Office will be notified immediately if extensive contamination is found within the laboratory or if any personnel are found to be contaminated.**
16. A record of the types and quantities of radionuclides possessed by each activity supervisor at a given time shall be maintained.
17. Radioactive materials shall be protected from unauthorized removal or access at all times (see Section 8.1).

12.3 Facility Audits and Radiation Surveys

In order to ensure that safety rules are observed and that radioactive materials are being controlled adequately, the ESH&A Office Health Physics Group will conduct periodic inspections of radionuclide laboratories. During the course of each inspection, both external radiation levels and surface contamination levels will be monitored. The activity supervisor's radionuclide inventory and contamination survey records will also be reviewed during inspections. Any problems encountered by Health Physics during the inspections will be discussed with the activity supervisor and, when necessary, with the Group Leader. A written report will be supplied to the Group Leader on all inspections.

13.0 EMERGENCY AND DECONTAMINATION PROCEDURES

Despite the strict adherence to all laboratory safety rules, it is possible that accidents involving radioactive material will occur on occasion. For this reason, it is important that radioactive material users are aware of the proper procedures to follow for various types of accidents. Reference should be made to the Ames Laboratory Procedure for managing radiation emergencies and emergency care for accident victims for more detailed instructions.

13.1 Minor Spills

Incidents involving the release or spillage of less than 100 microcuries of a radionuclide in a nonvolatile form can generally be regarded as minor. In such cases:

1. Notify all other persons in the room at once.
2. Clear the room of all persons except those needed to deal with the spill.
3. Confine the spill immediately. Liquids: Drop absorbent paper or chemical (e.g. calcium bentonite) on the spill. Standard "Spill Control Kits" are available from Chemistry Stores. Solids: Dampen thoroughly, taking care not to spread contamination. Use water, unless a chemical reaction would release air contaminants; otherwise use oil.
4. Notify the activity supervisor.
5. Notify the ESH&A Office (phone: 294-2153).
6. After hours, notify the Plant Protection Section.

13.2 Major Spills or Releases

An incident that occurs outside of the hood and involves the release of more than 100 microcuries of a radionuclide in a nonvolatile form, or the release of any amount of a radionuclide in a volatile form, should be considered "major." In such cases:

1. Evacuate the room immediately shutting doors and windows on the way out.
2. Notify the laboratory supervisor.
3. Notify the ESH&A Office (phone: 294-2153).
   After hours, notify the Plant Protection Section.
4. Post the laboratory door with a "Keep Out" sign.
5. Assemble those persons who were present in the laboratory near the entrance.
6. Wait for assistance.

13.3 Accidents Involving Personal Injury

For any accident involving personal injury, medical treatment or assistance will always be the first priority. This may involve administering first aid and/or calling 911 for emergency medical assistance. For accidents involving radioactive materials, contamination control and exposure control are also important but should never delay or impede medical assistance. If radioactive materials are involved, Health Physics Group must be notified as soon as possible. After the injured person is treated and removed from the accident site, the previously described procedures should be followed as appropriate.

13.4 Decontamination Procedures

If the decontamination is minor in nature (i.e., cleaning a table-top, small tools, etc.), the user is authorized to do these decontamination operations. After it is done they should contact Health Physics and request verification that the area is free of contamination and to dispose or radioactive waste generated from the decon. For larger areas or equipment Health Physics should be contacted to perform the decontamination. For most relatively minor contamination incidents, the following general steps should be taken upon discovery of the contamination:

1. Mark the perimeter of the contaminated area.
2. Notify Health Physics of the contamination so that they can more accurately assess the extent of the contamination and advise and assist in the decontamination effort.
3. Assemble cleaning supplies such as paper towels, detergent in water, plastic bags and plastic gloves.
4. Proceed with scrubbing the area from the borders to the center, cleaning small areas at a time.
5. Periodically monitor the effectiveness of the decontamination effort with surface wipes and instrument surveys (see Table 2 for contamination limits).
6. Place all contaminated cleaning materials such as paper towels, rags, and gloves in a plastic bag and label as radioactive waste.
7. Notify Health Physics upon completion of the decontamination effort so that a follow-up contamination survey can be made.

Table 2

Limits of Radioactive Contamination on Surfaces

[Taken from Appendix D to Title 10, Code of Federal Regulations, Part 835—"Surface Radioactivity Values"--except for portions on Direct Measurements.]

The data presented in the following table are to be used in identifying contamination and high contamination areas as defined in 10 CFR 835.2(a), identifying the need for surface contamination monitoring and control in accordance with 10 CFR 835.404, identifying the need for radioactive material controls in accordance with 10 CFR 835.1101.

SURFACE RADIOACTIVITY LIMITS[1] IN DPM/100 CM^2 and MILLIREM (mR)/HOUR

RADIONUCLIDE OR TYPE OFRADIATION	REMOVABLE. By use of smears of the surface [2,4]	TOTAL (Fixed + Removable). By use of smears and/or direct [9] measurements [2,3]
U-nat, U-235, U-238, and associated decay products.	1,000 dpm/100 cm^2 (alpha)	5,000 dpm/100 cm^2 (alpha)
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227,I-125, I-129.	20 dpm/100 cm^2	500 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133.	200 dpm/100 cm^2	1,000 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. [5]	1,000 dpm/100 cm^2	5,000 dpm/100 cm^2
Tritium and tritiated compounds. [6]	10,000 dpm/100 cm^2	N/A
Alpha	N/A	(Using Survey Instrument) Non-detectable [7]
Beta/Gamma	N/A	(Using Survey Instrument) 0.1 mR/hr @ 1 inch [8]

[1] The limits in this Table, with the exception noted in footnote 6, apply to radioactive contamination deposited on, but not incorporated into the interior of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides apply independently.

[2] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[3] The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface radioactivity value if: (1) from measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds three times the applicable value.

[4] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note - The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

[5] This category of radionuclides includes mixed fission products, including the Sr-90, which is present in them. It does not apply to Sr-90, which has been separated from the other fission products, or mixtures where the Sr-90 has been enriched.

[6] Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface radioactivity value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore a "Total" value does not apply.

[7] Non-detectable is a reading less than the average instrument background plus 10%.

[8] Reading from a survey instrument with the beta shield open and a maximum distance of 1 inch from the surface of the detector tube to the surface being monitored.

[9] Direct measurements are of the total fixed + removable contamination and recorded in dpm/100 cm^2 if an E-perm device is used or recorded in mR/hr if a standard radiation survey instrument is used.

14.0 RADIATION-PRODUCING DEVICES

14.1 Analytical X-Ray Equipment

Individuals using analytical x-ray units may receive ring TLDs, a whole body TLD, or both, depending upon the particular type of device and use.

14.2 Electron Microscopes

Because of the very limited potential for radiation exposure from electron microscopes, neither personnel monitoring nor formal safety training is required for users of these devices.

15.0 APPENDICES

- **Forms**
- **Guidelines**
- **Glossary**

APPENDIX A

Ames Laboratory
Environment, Safety, Health & Assurance
APPLICATION FOR USE OF RADIOACTIVE MATERIALS

Information on Individual User

1. Name: ______________________________ 2. Group: _______________________

3. Group Leader: _______________________ 4. Program: _____________________

5. Ames Lab Address: ___________________ 6. Telephone #:__________________

7. Other personnel working on this Activity:
____

8. Education, training and experience of all personnel:
____

Information on proposed activity

9. Provide a brief description of the proposed activity (State the purpose, procedures, list of equipment, activities of sources, safety precautions, etc. Also provide diagrams as necessary. Use back of this form if necessary):
____

10. Radioactive Source Information

Item #	Radioisotope	Total Quantity	Quantity per Experiment	Chemical Form
1				
2				
3				
4				

11. Period of usage of above isotopes: ____

Facility Information

12. Attach plans of the laboratory, giving the name of the building and room number. Show the locations of fume hoods, sinks, lab benches, etc. If necessary for the proposed usage, describe special features, such as thickness of walls and ceilings, occupancy of adjacent areas, contamination control procedures, etc:
____
____

Approval

We certify that we have reviewed the Ames Laboratory Radiological Control Manual, 10 CFR 835, and the Ames Laboratory Radiological Protection Program and that this application is in accordance with those documents.

Applicant _______________________________________ Group Leader
____

Send one copy to Environment, Safety & Health, G40 TASF. Retain one copy for your files.

ESH&A Office Form #10202.003
June 1999

APPENDIX B

Ames Laboratory
Environment, Safety, Health & Assurance
APPLICATION FOR USE OF RADIATION-PRODUCING MACHINES

Information on Individual User

1. Name: ________________________ 2. Group: ________________________________

3. Group Leader: _________________ 4. Program: _____________________________

5. Ames Lab Address: _____________ 6. Telephone #: __________________________

7. Other personnel working on this Activity:
____
____

8. Education, training and experience of all personnel:
____
____

Information on proposed activity

9. Provide a brief description of the proposed activity (State the purpose, procedures, list of equipment, procedures, safety precautions, etc. Also provide diagrams as necessary. Use back of this form if necessary):
____
____

Radiation-Producing Machine Information

10. Brief Description of Device(s): (State the manufacturer, year of manufacture, model number, serial number, maximum mA and kV, etc. Use the back of this form to continue, if necessary)
____
____
____

11. Period of usage of above radiation-producing machines:
____

Facility Information

12. Attach plans of the laboratory, giving the name of the building and room number. Show the locations of fume hoods, sinks, lab benches, etc. If necessary for the proposed usage, describe special features, such as thickness of walls and ceilings, occupancy of adjacent areas, contamination control procedures, etc:
____
____

13. Approval

We certify that we have reviewed the Ames Laboratory Radiological Control Manual, 10 CFR 835, and the Ames Laboratory Radiological Protection Program and that this application is in accordance with those documents.

Applicant _______________________________________ Group Leader
____

Send one copy to Environment, Safety & Health, G40 TASF. Retain one copy for your files.

APPENDIX C

RADIOACTIVE MATERIAL OR RADIATION-PRODUCING MACHINE USE AUTHORIZATION

AMES LABORATORY

Activity Supervisor: ________________________ **Department:** ________________

Office/Lab Phone:__________________________ **Office:**_______________________

Application Date: ___________

Amendment No. ____________

A1. AUTHORIZED RADIONUCLIDES AND AMOUNTS

Nuclide	Possession Limit (mCi)	Chemical/Physical Form

A2. AUTHORIZED RADIATION-PRODUCING MACHINE(S)

Location	Manufacturer & Model #	Maximum mA and kV

B. AUTHORIZED USE

C. AUTHORIZED LOCATIONS OF USE AND STORAGE

D. AUTHORIZED PERSONNEL

E. CONDITIONS AND RESTRICTIONS

All DOE and Ames Laboratory rules, policies, and procedures concerning the possession and use of radioactive material or radiation-producing machines, as detailed in the Radiological Protection Program and other applicable regulations, will be observed during the activities.

Approved by:

_______________________________________ ____________

Radiation Safety Officer Date

_______________________________________ ____________

Chairman, ALARA Committee Date

APPENDIX D

APPENDIX E

Checklist for Initiating the Use of Radioactive Material

Ames Laboratory
Environment, Safety, Health and Assurance Office

APPLICATION PROCESS

__________________ 1. Request a copy of the form, "Application for Use Radioactive Materials" from the ESH&A Office at 294-7922 or 294-7926.

__________________ 2. Complete the application for use with the information detailed in Section 4.1 of this Manual.

__________________ 3. Forward the application to the ESH&A Office, G40 TASF and wait for notification of its status.

TRAINING

__________________ 4. Contact the ESH&A Office to sign up for the Radiation Training Course.

__________________ 5. Complete the radiation training course.

__________________ 6. Complete the Radiation Safety Exam.

AUTHORIZATION FOR USE

__________________ 7. Review carefully the written notification from the ALARA Committee concerning your application's approval (note conditions for use and possession limits.)

__________________ 8. Review Section 6.0 of the Radiation Safety Manual, "Activity Supervisor Responsibilities."

PREPARATION FOR USE

__________________ 9. Contact the ESH&A Office to arrange for the set-up of your laboratory for radionuclide use.

__________________ 10. Review waste handling procedures (Section 9.0), laboratory rules (Subsection 12.2) and other operational information within this Manual.

__________________ 11. Meet with the ESH&A Office staff person during laboratory set-up to discuss any questions you may have regarding operational matters.

ORDERING MATERIALS

__________________ 12. Review the procedure for ordering radioactive material (Subsection 7.1 of this Manual) and follow it carefully during ordering.

ESH&A Form #10202.006
June 1999

APPENDIX F

RADIATION SAFETY LABORATORY AUDIT
Environment, Safety, Health and Assurance Office

Laboratory: ______________________________

Activity Supervisor: ______________________________

Survey by: ____________________ **Date:** ____________________

1.0 Postings/Labeling

Yes	No	N/A	
☐	☐	☐	Door Label Posted and Filled Out……1.1
☐	☐	☐	Radiation Safety Rules Posted ……..1.2
☐	☐	☐	Radiation Safety Guide Posted ……….1.3
☐	☐	☐	Appropriate Radiation Labeling…….. 1.4

2.0 Survey Meters

Yes	No	N/A	
☐	☐	☐	Current Calibration……………………2.1
☐	☐	☐	Battery/Response Check Okay……….2.2
☐	☐	☐	Staff Proficient in Use………..………2.3

3.0 Radioactive Waste

Yes	No	N/A	
☐	☐	☐	Waste Labeled Properly………………3.1
☐	☐	☐	Adequate Spill Control Measures…….3.2
☐	☐	☐	Appropriate Shielding…………………3.3
☐	☐	☐	Notice to Employees Posted…………..3.4
☐	☐	☐	Door Label Posted and Filled Out……3.5

4.0 Records

Yes	No	N/A	
☐	☐	☐	Inventory System Used and Current..4.1
☐	☐	☐	Surveys Completed and Recorded……4.2
☐	☐	☐	Radiation Safety Manual Available....4.3
☐	☐	☐	Copy of Current Authorization……….4.4

5.0 Security

Yes	No	N/A	
☐	☐	☐	Laboratory Attended…………………..5.1
☐	☐	☐	RAM Secure…………………………....5.2

Laboratory: ______________________________

Activity Supervisor: ______________________________

Survey By: ______________________________

Date: ______________________________

6.0 Chemical Safety

Yes	No	N/A	
☐	☐	☐	Chem Hygiene Plan Available……….6.1
☐	☐	☐	MSDS File Available……………….....6.2
☐	☐	☐	Flammable Mat. Stored Properly…....6.3
☐	☐	☐	No Incompatible Chemical Storage.....6.4
☐	☐	☐	All Containers Labeled………………..6.5
☐	☐	☐	Designated Waste Chem Sto. Area….6.6
☐	☐	☐	Chem Waste Labeled & Dated……….6.7

7.0 Industrial Hygiene

Yes	No	N/A	
☐	☐	☐	Fire Extinguisher Accessible…………7.1
☐	☐	☐	First Aid Kit Available……………….7.2
☐	☐	☐	Showers and Eye Wash Accessible…..7.3
☐	☐	☐	No Electrical Hazards…………………7.4
☐	☐	☐	Aisle/Exits Clear……………………….7.5

8.0 Miscellaneous Safety

Yes	No	N/A	
☐	☐	☐	No Eating/Drinking in Lab…………...8.1
☐	☐	☐	Spill Kit Available………..……………8.2
☐	☐	☐	Compressed Gas Cylinders Secure…..8.3

Yes	No	
☐	☐	Rad contamination found? (If yes, see attached "Survey results" form.)

Yes	No	
☐	☐	Written Response required by Activity Supervisor? (If yes, see attached "Written Response" form.)

Reviewed by: ______________________________

Date: ______________________________

ESH&A Form #10202.007

APPENDIX G

Guidelines for the Safe Use of Common Radionuclides

Guidelines for the Safe Use of Common Radionuclides

^{232}Th
Thorium

HALF LIFE

Physical	Biological	Effective
1.4E10 years	3000 days	3000 days

Th-232 RADIATION EMITTED

Type	Energy (max)	Range (max)
Alpha	4.01 MeV	2.35 cm (in air @ 1 atm and 15° C)

Th-232 DAUGHTERS - PRINCIPAL RADIATIONS EMITTED

Nuclide	Half-life	Type	Energy (max)	Range (max)
Ra-228	5.75 yrs	Beta	0.039 MeV	Air – 14 cm Tissue – 195 μm
Ac-228	6.13 hrs	Beta	1.17 Mev	Air – 4.3 m Tissue – 6 mm
		Gamma	0.911 MeV (27.7%)	
Th-228	1.9 yrs	Alpha	5.42 MeV	4.1 cm (in air @ 1 atm and 15° C)
		Gamma	0.84 Mev (1.2 %)	
Ra-224	3.7 days	Alpha	5.7 MeV	4.5 cm (in air @ 1 atm and 15° C)
Rn-220	55.6 sec	Alpha	6.3 Mev	5.2 cm (in air @ 1 atm and 15° C)
Po-216	0.15 sec	Alpha	6.8 Mev	5.8 cm (in air @ 1 atm and 15° C)
Pb-212	10.64 hrs	Beta	0.334 Mev	Air – 1.2 m Tissue – 1.1 mm
		Gamma	0.24 MeV (44.6%)	
Bi-212	60.55 min	Alpha	6.1 MeV	4.9 cm (in air @ 1 atm and 15° C)
		Beta	2.3 MeV	Air – 8.4 m Tissue – 11.5 mm
		Gamma	1.6 MeV (2.75%)	

Po-212	305 ηs	Alpha	8.9 MeV	8.4 cm (in air @ 1 atm and 15° C)

Th-232 DAUGHTERS - PRINCIPAL RADIATIONS EMITTED (Continued)

Tl-208	3.07 min	Beta	1.8 MeV	Air – 6.6 m Tissue – 9 mm
		Gamma	2.6 MeV (100%)	
Pb-208	Stable			

Guidelines for the Safe Use of Common Radionuclides

^{232}Th
Thorium

RADIATION HAZARDS

Nuclide	External Hazards: Dose rate from a **1 mCi** (37 MBq) point source: @ 1 Meter	External Hazards: @ 1 Centimeter	Internal Hazards: Effective Committed Dose Equivalent per Unit Intake[1]: Ingestion	Effective Committed Dose Equivalent per Unit Intake[1]: Inhalation	Annual Limit on Intake (ALI):[2] Ingestion	Annual Limit on Intake (ALI):[2] Inhalation
Th-232	N/A	N/A	2.7E3 mrem/µCi (7.4E-7 Sv/Bq)	1.6E6 mrem/µCi (4.4E-4 Sv/Bq)	0.7 µCi (26 kBq)	0.003 µCi 11.1 kBq
Ra-228	N/A	N/A	1.4E3 mrem/µCi (3.9E-7 Sv/Bq)	4.8E3 mrem/µCi (1.3E-6 Sv/Bq)	2.0 µCi (74 kBq)	1.0 µCi (37 kBq)
Ac-228	Beta: 30 mRem/hr (0.3 mSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr)				
	Gamma: 126 µRem/hr (1.26 µSv/hr)	Gamma: 1.3 Rem/hr (130 mSv/hr)	2.2E0 mrem/µCi (5.85E-10 Sv/Bq)	1.3E2 mrem/µCi (3.4E-8 Sv/Bq)	2000 µCi (7.4E4 kBq)	9.0 µCi (3.3E2 kBq)
Th-228	Gamma: 5.0 µRem/hr (.05 µSv/hr)	Gamma: 50 mRem/hr (500 µSv/hr)	4.1E2 mrem/µCi (1.1E-7 Sv/Bq)	5.5E5 mrem/µCi (6.75E-5 Sv/Bq)	6 µCi (2.2E2 kBq)	.02 µCi (0.74 kBq)
Ra-224	N/A	N/A	3.7E2 mrem/µCi (9.9E-8 Sv/Bq)	3.2E3 mrem/µCi (8.5E-7 Sv/Bq)	8 µCi (3E2 kBq)	2 µCi (74 kBq)
Rn-220	N/A	N/A	N/A	N/A	N/A	20 µCi (740 kBq)
Po-216	N/A	N/A	N/A	N/A	N/A	N/A
Pb-212	Gamma: 54 µRem/hr (0.5 µSv/hr)	Gamma: 540 mRem/hr (5.4 mSv/hr)	.46 mrem/µCi (1.23E-8 Sv/Bq)	1.7E2 mrem/µCi (4.6E-8 Sv/Bq)	80 µCi (3E3 kBq)	30 µCi (1.1E3 kBq)
Bi-212	Beta: 30 mRem/hr (0.3 mSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr)				
	Gamma: : 22 µRem/hr (.02 µSv/hr)	Gamma: 220 mRem/hr (2.2 µSv/hr)	1.1 mrem/µCi (2.87E-10 Sv/Bq)	21.5 mrem/µCi (5.83E-9 Sv/Bq)	5E3 µCi (2E5 kBq)	200 µCi (7.4E3 kBq)
Po-212	N/A	N/A	N/A	N/A	N/A	N/A
Tl-208	Beta: 30 mRem/hr (0.3 mSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr)				
	Gamma: 1.3 mRem/hr (.013 mSv/hr)	Gamma: 13 Rem/hr (130 mSv/hr)	N/A	N/A	N/A	N/A

[1] Effective Committed Dose Equivalents taken from the Environmental Protection Agency's Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion" Oak Ridge National Laboratory, 1989.
[2] ALIs are from the revised 10CFR20.

SPECIAL CONSIDERATIONS

- Th-232 and its daughters emit relatively energetic alpha particles, which can pose a significant internal hazard.
- Because of its long effective half-life, Th-232 and its daughters have low annual limits on intake.

RADIATION SAFETY PRACTICES

Dosimetry - Whole body TLD badge and ring TLDs are required when working with or around quantities of 1 mCi or more.

Bioassay – Required for individuals where a significant uptake of material is suspected.

Shielding – Use shielding as necessary to reduce the exposure rate from thorium sources, which will vary with the amount of material being used.

Surveys – GM meter surveys, wipes analyzed in alpha/beta proportional counter or germanium detector.

General – Respiratory protection with HEPA filtration filters and full Personnel Protective Equipment should be worn around sources of Th-232 that can become airborne or in areas contaminated with Th-232.

Guidelines for the Safe Use of Common Radionuclides

^{238}U
Uranium

HALF LIFE

Physical	Biological	Effective
4.47E9 years	1449 days	1449 days

U-238 RADIATION EMITTED

Type	Energy (max)	Range (max)
Alpha	4.20 MeV	2.59 cm (in air @ 1 atm and 15° C)

U-238 DAUGHTERS - PRINCIPAL RADIATIONS EMITTED

Nuclide	Half-life	Type	Energy (max)	Range (max)
Th-234	24.1 days	Beta	0.188 MeV	Air – 69 cm Tissue – 1 mm
		Gamma	1.001 MeV (59%)	
Pa-234m	1.17 min.	Beta	2.28 MeV	Air – 8.3 m Tissue – 11.4 mm
		Gamma	1.0 MeV (59%)	
Pa-234	6.7 hrs	Beta	0.224 Mev (ave.)	Air – 0.8 m Tissue - 1 mm
		Gamma	0.883 MeV (11.8%)	
		Gamma	0.132 MeV (19.7%)	
		Gamma	0.946 MeV (12%)	
U-234	2.5E5 yrs	Alpha	4.77 MeV	3.3 cm (in air @ 1 atm and 15° C)
Th-230	7.7E4 yrs	Alpha	4.69 MeV	3.2 cm (in air @ 1 atm and 15° C)
Ra-226	1600 yrs	Alpha	4.78 MeV	3.3 cm (in air @ 1 atm and 15° C)
		Gamma	0.186 MeV (3.3%)	
Rn-222	3.8 days	Alpha	5.5 MeV	4.2 cm (in air @ 1 atm and 15° C)
Po-218	3.05 min	Alpha	6.0 MeV	4.8 cm (in air @ 1 atm and 15° C)
		Gamma	0..837 MeV (0.001%)	

Pb-214	2 seconds	Alpha	6.7 MeV	5.7 cm (in air @ 1 atm and 15° C)
Bi-214	19.9 min	Alpha	5.5 MeV	4.2 cm (in air @ 1 atm and 15° C)
Po-214	164 μs	Alpha	7.7 MeV	6.9 cm (in air @ 1 atm and 15° C)
		Gamma	0.799 MeV (1%)	

U-238 DAUGHTERS - PRINCIPAL RADIATIONS EMITTED (continued)

Nuclide	Half-life	Type	Energy (max)	Range (max)
Tl-210	1.3 min	Beta	1.87 MeV	Air – 6.8 m Tissue – 9.4 mm
		Gamma	0.292 MeV (79%)	
Pb-210	22.3 yrs	Beta	0.016 MeV	Air – 5.9 cm Tissue – 8 μm
		Gamma	0.046 MeV (4%)	
Bi-210	5.01 days	Alpha	4.7 MeV	3.2 cm (in air @ 1 atm and 15° C)
		Beta	1.161 MeV	Air – 4.2 m Tissue – 5.8 mm
Po-210	138 days	Alpha	5.3 MeV	4.0 cm (in air @ 1 atm and 15° C)
Tl-206	4.2 min	Beta	1.57 MeV	Air – 5.7 m Tissue – 8 mm
Pb-206	Stable			

^{238}U

Uranium

RADIATION HAZARDS

Nuclide	External Hazards: Dose rate from a **1 mCi** (37 MBq) point source: @ 1 Meter	@ 1 Centimeter	Internal Hazards: Effective Committed Dose Equivalent per Unit Intake[1]: Ingestion	Inhalation	Annual Limit on Intake (ALI):[2] Ingestion	Inhalation
U-238	N/A	N/A	2.6E2 mrem/µCi (6.9E-8 Sv/Bq)	2.5E3 mrem/µCi (6.6E-7 Sv/Bq)	10.0 µCi (370 kBq)	1.0 µCi (37 kBq)
Th-234	Beta: 30 mRem/hr (0.3 mSv/hr) Gamma: 295 µRem/hr (0.3 µSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr) Gamma: 3.0 Rem/hr (30 mSv/hr)	1.4E1 mrem/µCi (3.69E-9 Sv/Bq)	3.0E1 mrem/µCi (8.0E-9 Sv/Bq)	10.0 µCi (370 kBq)	1.0 µCi (37 kBq)
Pa-234m	Beta: 30 mRem/hr (0.3 mSv/hr) Gamma: 295 µRem/hr (0.3 µSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr) Gamma: 3.0 Rem/hr (30 mSv/hr)				
Pa-234	Beta: 30 mRem/hr (0.3 mSv/hr) Gamma: 52 µRem/hr (0.52 µSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr) Gamma: 520 mRem/hr (5.2 mSv/hr)	2.1 mrem/µCi (5.8E-10Sv/Bq)	0.7 mrem/µCi (1.9E-10 Sv/Bq)	2000 µCi (74 MBq)	8000 µCi (296 MBq)
U-234	N/A	N/A	2.8E2 mrem/µCi (7.7E-8 Sv/Bq)	2.7E3 mrem/µCi (7.4E-7 Sv/Bq)	10.0 µCi (370 kBq)	1.0 µCi (37 kBq)
Th-230	N/A	N/A	5.5E2 mrem/µCi (1.5E-7 Sv/Bq)	3.3E5 mrem/µCi (8.8E-5 Sv/Bq)	4.0 µCi (74 kBq)	0.006 µCi (0.2 kBq)
Ra-226	Gamma: 3 µRem/hr (0.03 µSv/hr)	Gamma: 31 mRem/hr (310 µSv/hr)	1.3E3 mrem/µCi (3.6E-7 Sv/Bq)	8.5E3 mrem/µCi (2.3E-6 Sv/Bq)	2.0 µCi (74 kBq)	0.6 µCi (22 kBq)
Rn-222	N/A	N/A				With daughters 100 µCi (3.7 MBq)
Po-218	Gamma: : 0.4 µRem/hr (0.004 µSv/hr))	Gamma: 4.2 mRem/hr (42 µSv/hr)				
Pb-214	N/A	N/A	0.63 mrem/µCi (1.7E-10 Sv/Bq)	7.7 mrem/µCi (2.1E-9 Sv/Bq)	9000 µCi (333 MBq)	800 µCi (29.6 MBq)
Bi-214	N/A	N/A	2.8e-1 mrem/µCi (7.6E-11 Sv/Bq)	6.7 mrem/µCi (1.8E-9 Sv/Bq)	2000 µCi (74 MBq)	800 µCi (29.6 MBq)
Po-214	N/A	N/A				
Tl-210	Beta: 30 mRem/hr (0.3 mSv/hr) Gamma: 0.11 mRem/hr (11 µSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr) Gamma: 1.1Rem/hr (11 mSv/hr)				
Pb-210	N/A	N/A	5.4 Rem/µCi (1.5E-6 Sv/Bq)	13 Rem/µCi (3.67E-6 Sv/Bq)	2000 µCi (74 MBq)	800 µCi (29.6 MBq)
Bi-210	N/A	N/A	6.6 mrem/µCi (1.7E-9 Sv/Bq)	15.5 mrem/µCi (4.18E-9 Sv/Bq)	800 µCi (29.6 MBq)	200 µCi (7.4 MBq)
Po-210	N/A	N/A	1.9 mrem/µCi (5.1E-7 Sv/Bq)	9.4 mrem/µCi (2.5E-6 Sv/Bq)	3 µCi (111 kBq)	0.6 µCi (22.2 MBq)
Tl-206	Beta: 30 mRem/hr (0.3 mSv/hr)	Beta: 300 Rem/hr (3.0 Sv/hr)				
Pb-206	Stable					

[1] Effective Committed Dose Equivalents taken from the Environmental Protection Agency's Federal Guidance Report No. 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion” Oak Ridge National Laboratory, 1989.

[2] ALIs are from the revised 10CFR20.

SPECIAL CONSIDERATIONS

- U-238 and its daughters emit relatively energetic alpha particles, which can pose a significant internal hazard.
- Because of its long effective half-life, U-238 and its daughters have low annual limits on intake.

- Beta radiation poses a significant external radiation hazard.

RADIATION SAFETY PRACTICES

Dosimetry - Whole body TLD badge and ring TLDs are required when working with or around quantities of 1 mCi or more.

Bioassay – Required for individuals where a significant uptake of material is suspected.

Shielding – Use as appropriate for amount of material.

Surveys – GM meter surveys, wipes analyzed in alpha/beta proportional counter or germanium detector.

General – Respiratory protection with HEPA filtration filters and full Personnel Protective Equipment should be worn around sources of U-238 that can become airborne or in areas contaminated with U-238.

APPENDIX H

AMES LABORATORY
Office of Environment, Safety, Health & Assurance

DECLARATION OF PREGNANCY

Name of Individual ____

Social Security Number ____

Date of Conception (Mo./Yr.) ____

By providing this information to my immediate supervisor, in writing, I am declaring myself to be pregnant as of the date shown above. Under the provisions of 10 CFR 835.206, I understand that my dose will not be allowed to exceed 500 mrem (5 mSv) during my entire pregnancy from occupational exposure to radiation. I under stand this limit includes exposure I have already received. When the pregnancy has ended, I will inform my supervisor and the Environment, Safety, Health & Assurance Office as soon as practical. I also understand I have the right to revoke this declaration of pregnancy at any time and such revocation must be made in writing to the Environment, Safety, Health & Assurance Office.

Signature of Individual ____

Date signed ____

RECEIPT OF DECLARATION OF PREGNANCY

Name of Supervisor ____

I have received notification from the above-named individual that she is pregnant. I have explained to her the potential risks from exposure to radiation. I have evaluated her prior radiation dose and established appropriate limits to control the dose to the developing unborn child in accordance with the limits in 10 CFR 835.206. I have explained to her options for reducing her exposure to As Low As Reasonably Achievable (ALARA) levels.

Signature of Supervisor ____

Date Signed ____

Send this completed form to the Health Physics Group, Environment, Safety, Health and Assurance Office, G40A, TASF. The information furnished on this form will be used and maintained pursuant to 5 U.S.C. 552a(e)(3), enacted into law by Section 3 of the Privacy Act of 1974 (Public Law 93-579).

ESH&A Form #10202.008
June 1999

APPENDIX I

Glossary

Absorbed Dose - the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad, which is 100 ergs/gram.

Absorption - the phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

Activation - the process of making a material radioactive by bombardment with neutrons, protons, or other nuclear radiation.

Activity - the rate of disintegration or transformation or decay of radioactive material. The units of activity are the becqueral (bq) and the curie (Ci).

Activity Supervisor - a staff member, assistant professor or higher (no visiting faculty), employed by the Laboratory, who has been approved through the Radiation Safety Committee for the purchase and use of radioactive materials or use of radiation-producing machines. Activity Supervisors seeking approval must fill out applications describing the isotopes and activities to be used as well as the procedures, survey equipment and techniques and other pertinent information prior to approval.

Acute Exposure - the absorption of a relatively large amount of radiation (or intake of radioactive material) over a short period of time.

Acute Health Effects - prompt radiation effects (those that would be observable within a short period of time) for which the severity of the effect varies with the dose, and for which a practical threshold exists.

Adult - an individual 18 or more years of age.

ALARA (acronym for As Low As Reasonably Achievable) - making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and radioactive materials in the public interest.

Alpha Particle - a strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

Annual Limit on Intake (ALI) - the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by a reference person that would result in a committed effective dose equivalent of 5 rem (0.05 Sv) or a committed effective dose equivalent of 50 rem (0.5 Sv) to any individual organ or tissue.

Atom - smallest particle of an element which is capable of entering into a chemical reaction.

Attenuation - the process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.

Background Radiation - ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

Beta Particle - charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Bioassay - the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Body Burden - the amount of radioactive material which if deposited in the total body will produce the maximum permissible dose rate to the critical organ.

Bremsstrahlung - electromagnetic (x-ray) radiation produced by the deposition of charged particles in matter. Usually associated with energetic beta emitters, e.g., phosphorus-32.

Calibration - determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors.

Charged Particle - an ion. An elementary particle carrying a positive or negative electric charge.

Chronic Exposure - the absorption of radiation (or intake of radioactive materials over a long period of time), i.e., over a lifetime.

Committed Dose Equivalent - the dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed Effective Dose Equivalent - the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Contamination, Radioactive - deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm caused may be a source of excessive exposure to personnel or the validity of an experiment or a procedure.

Controlled Area - an area, outside of a restricted area but inside the site boundary, access to which can be limited by the Laboratory for any reason.

Coulomb - the meter-kilogram-second unit of electric charge, equal to the quantity of charge transferred in one second by a constant current of one ampere.

Count - the external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse.

Critical Organ - the organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his descendants.

Curie - the quantity of any radioactive material in which the number of disintegrations is 3.7 x 1010 per second. Abbreviated Ci.

Daughter Products - isotopes that are formed by the radioactive decay of some other isotope. In the case of radium-226, for example, there are ten successive daughter products, ending in the stable isotope lead-206.

Decay, Radioactive - disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

Declared Pregnant Woman - a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Decontamination - the reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination, (2) letting the material stand so that the radioactivity is decreased as a result of natural decay, and (3) covering the contamination to shield or attenuate the radiation emitted.

Deep Dose Equivalent - applies to external whole-body exposure and is the dose equivalent at a tissue depth of one centimeter (1000 mg/cm^2).

Department of Transportation (DOT) - a governmental agency responsible for promoting the safe transportation of hazardous materials by all modes. (land, air, water).

Disintegration - see decay, radioactive.

Dose or Radiation Dose - a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose Rate - the radiation dose delivered per unit of time. Measured, for example, in rem per hour.

Dosimeter - a portable instrument for measuring and registering the total accumulated exposure to ionizing radiation. (see dosimetry.)

Dosimetry - the theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made. (see film badge; thermoluminescent dosimeter; Geiger-Mueller counter.)

Effective Dose Equivalent - the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

Efficiency - (radiation detection instrument) a measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so be aware of which factors (window, transmission, sensitive volume, energy dependence, etc.) are included in a given case. Efficiency refers to the percent of total activity present for a given nuclide detected by the radiation detection instrument being used.

Electron - negatively charged elementary particle, which is a constituent of every neutral atom. Its unit of negative electricity equals 4.8 x 10 –19 coulombs. Its mass is 0.00549 atomic mass units.

Electron Volt - a unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviated eV. Radioisotopic energy is typically measured in MeV. (million electron volts)

Erg - the unit of energy or work in the centimeter-gram-second system; the work performed by a force acting over a distance of one centimeter so as to result in a one gram mass being accelerated at a rate of one centimeter per second each second.

Exposure - (1) being exposed to ionizing radiation or radioactive material. (2) a measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of air in the volume element. The special unit of exposure is the Roentgen.

Extremity - hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye Dose Equivalent - applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

Film Badge - a packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films of differing sensitivity, and it may contain filters, which shield parts of the film from certain types of radiation.

Fission- the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

Gamma Ray - very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to x-ray.

Geiger-Mueller - (G-M) Counter a radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation.

Gray (Gy) - the SI unit of absorbed dose. One Gray is equal to one joule per kilogram (100 rad).

Half-Life, Biological - time required for the body to eliminate 50 % of a dose of any substance by the regular processes of elimination. This time is approximately the same for both stable isotopes and radionuclides of a particular element.

Half-Life, Effective - time required for a radioactive nuclide in a system to be diminished by 50 % as a result of the combined action of radioactive decay and biological elimination.

Effective half-life = Biological half-life x Radioactive half-life / Biological half-life + Radioactive half-life

Half-Life, Radioactive - time required for a radioactive substance to lose 50 % of its activity by decay. Each radionuclide has a unique half-life.

Half Value Layer - the thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value.

Health Physics - a term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects of ionizing radiation.

High Radiation Area - an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mrem (1 mSv) in one hour at thirty centimeters from the radiation source or from any surface that the radiation penetrates.

Hot Spot - the region in a radiation/contamination area in which the level of radiation/contamination is noticeably greater than in neighboring regions in the area.

Individual Monitoring Devices - devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal air sampling devices.

Inverse Square Law - the intensity of radiation at any distance from a point source varies inversely as the square of that distance. For example: if the radiation exposure is 100 R/hr at 1 inch from a source, the exposure will be 0.01 R/hr at 100 inches.

Ion - an atom that has too many or too few electrons, causing it to be chemically active; such as an electron that is not associated (in orbit) with a nucleus. Ions may be positively or negatively charged, and vary in size.

Ionization - the process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ionization Chamber - an instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

Ionizing Radiation - alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and other particles or electromagnetic radiation capable of producing ions.

Isotopes - nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

Joule - the meter-kilogram-second unit of work or energy, equal to the work done by a force of one Newton when its point of application moves through a distance of one meter in the direction of the force.

Labeled Compound - a compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical or biological processes.

Limits - the permissible upper bounds of radiation exposures, contamination or releases.

Member of the Public - an individual, except when that individual is receiving an occupational dose.

Microcurie (µCi) - a one-millionth part of a curie. (1/1,000,000th), (.000001 Ci). (see curie.)

Millicurie (mCi) - a one-thousandth of a curie. (1/1000th), (.001 Ci). (see curie.)

MilliRoentgen (mR) - a sub multiple of the Roentgen equal to one-thousandth (1/1000th) of a Roentgen. (see Roentgen.)

Minor - an individual less than 18 years of age.

Monitoring - the measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

NARM - naturally occurring or accelerator-produced radioactive material. It does not include by-product, source, or special nuclear material.

Natural Radiation - ionizing radiation, not from manmade sources, arising from radioactive material other than the one directly under consideration. Natural radiation due to cosmic rays, soil, natural radiation in the human body and other sources of natural radioactivity are always present. The levels of the natural radiation vary with location, weather patterns and time to some degree.

Neutron - elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

Non-Removable Contamination - contamination adhering to the surface of structures, areas, objects or personnel and will not readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

NORM - naturally occurring radioactive materials.

Nucleus - the small, central, positively charged region of an atom that carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which has a single proton, all atomic nuclei contain both protons and neutrons. The number of protons deter-mines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number.

Nuclide - a species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

Occupational Dose - the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from sources of radiation. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Photon - a quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays and x-rays are examples of photons.

Pig - a container (usually lead) used to ship or store radioactive materials. The thick walls protect the person handling the container from radiation. Large containers are commonly called casks.

Pocket Dosimeter - a small ionization detection instrument that indicates radiation exposure directly. An auxiliary charging device is usually necessary.

Positron - particle equal in mass, but opposite in charge, to the electron; a positive charge.

Protective Barriers - barriers of radiation absorbing material, such as lead, concrete, plaster and plastic, that are used to reduce radiation exposure.

Proton - an elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

Public Dose - the dose received by a member of the public from exposure to radiation and to radioactive material released by the Laboratory, or to another source of radiation either within a Laboratory's controlled area or in unrestricted areas. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Quality Factor - a modifying factor that is used to derive dose equivalent from absorbed dose. It corrects for varying risk potential due to the type of radiation.

Rad - the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram.

Radiation Area - an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in one hour at thirty centimeters from the radiation source or from any surface that the radiation penetrates.

Radiation Worker - an individual who uses radioactive materials under the Laboratory's control. Individuals must be trained and have passed a radiation safety examination prior to beginning work with radioactive materials.

Radioisotope - a nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

Radiology - that branch of medicine dealing with the diagnostic and therapeutic applications of radiant energy, including x-rays and radioisotopes.

Radionuclide - a radioactive isotope of an element.

Radiosensitivity - the relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation. Radiotoxicity term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.

Relative Biological Effectiveness - for a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

REM - the special unit of dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor. (1 rem = .001 sievert)

Removable Contamination - contamination deposited on the surface of structures, areas, objects or personnel that can readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

Restricted Area - an area, access to which is limited by the Laboratory for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Roentgen (R) - the quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 gram of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. Amount of energy is equal to 2.58 x 10 -4 coulombs/kg air. The Roentgen is a special unit of exposure.

Scintillation Counter - a counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube.

Sealed Source - radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions which are likely to be encountered in normal use and handling.

Seivert - the SI unit of any of the quantities expressed as doe equivalent. The dose equivalent in Seivert is equal to the absorbed dose in Gray multiplied by the quality factor. (1 Sv = 100 rem)

Shallow Dose Equivalent - applies to the external exposure of the skin or an extremity and is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm 2) averaged over an area of one square centimeter.

Shielding Material - any material, which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in some cases eliminate it. Lead, concrete, aluminum, water and plastic are examples of commonly used shielding material.

SI - the abbreviation for the International System of Units.

Site Boundary - that line beyond which the land or property is not owned, leased, or otherwise controlled by the Laboratory.

Smear - (smear or swipe test) a procedure in which a swab, e.g., filter paper or cotton tipped applicator, is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose (removable) radioactive material.

Specific Activity - total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

Stable Isotope - an isotope that does not undergo radioactive decay. Survey an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Thermoluminescent Dosimeter (TLD) - crystalline materials that emit light if they are heated after being they have been exposed to radiation.

Total Effective Dose Equivalent - the sum of the deep dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Tracer, Isotopic - the isotope or non natural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

Unrestricted Area - an area, access to, which is neither limited nor controlled by the Laboratory.

Unstable Isotope - a radioisotope.

Very High Radiation Area - an area accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at one meter from a source of radiation or from any surface that the radiation penetrates.

X-Rays - penetrating electromagnetic radiation having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extra-nuclear part of the atom as x-rays. These rays are sometimes called Roentgen rays after their discoverer, W.C. Roentgen.